Single-Pilot Workload Management

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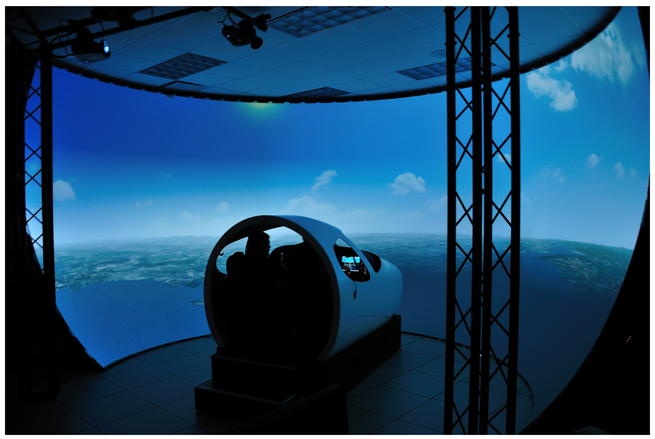
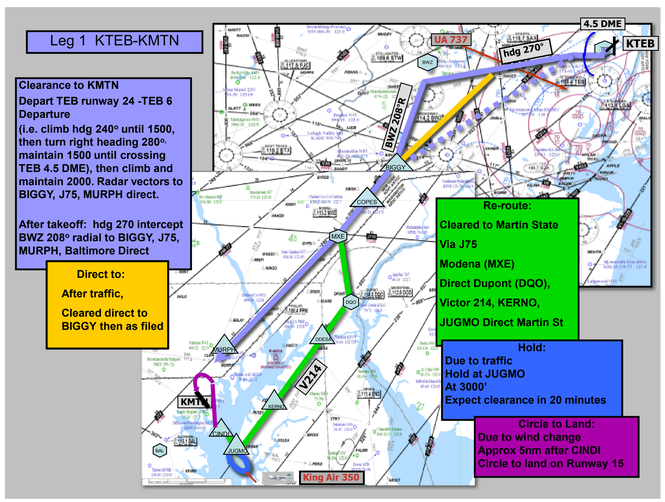
INTRODUCTION: Integrated glass cockpit systems place a heavy cognitive load on pilots (Burian & Dismukes, 2007). Researchers from the NASA Ames Flight Cognition Lab and the FAA Flight Deck Human Factors Lab examined task and workload management by single pilots. This poster describes pilot performance regarding programming a reroute while at cruise and meeting a waypoint crossing restriction on the initial descent.



METHOD: Thirteen certificated Cessna Citation Mustang (C510-S) pilots flew an experimental flight with two navigational legs involving high workload management in a Cessna Citation Mustang simulator (see above). While en route in the northeast corridor, we asked participants to reroute from their original flight path and meet a crossing restriction on the descent. Air Traffic Control (ATC) called to provide the pilots with their reroute clearance as the COPES waypoint was crossed, just 18.6 nm before Modena (MXE); the reroute now required a turn toward Dupont (DQO). Original route and reroute are shown below.



RESULTS: Of the thirteen participating pilots, more than half (n = 8) had difficulty programming and flying the reroute. There was a mixture of errors in completing the reroute including: not crossing DQO, programming the turn to DQO after having flown past MXE, not effectively managing the waypoints in the clearance, and not meeting the crossing restriction at DQO. Seven of the pilots (53%) had some difficulty completing the reroute. Four (30%) failed to meet the crossing restriction. Of note, no difference was found between owner-operators and professional pilots in terms of successfully completing the reroute and the crossing restriction.

Understanding the clearance with enough time to enter changes into the flight plan aided orderly management of the flight. Those that had fewer errors in understanding the revised clearance had more time to make changes to their flight plan before arriving at MXE and were more likely successful in completing the reroute (t-test was significant, $t(8) = -2.785$, $p = .24$). It was also found that interleaving tasks (such as checking paper charts) could result in an extension of the time taken to enter the reroute information.

Correctly Copying Reroute Clearance

	Number of times Instructions were Given					Distance from MXE (nm)				
	Mean	Mdn	Min	Max	SD	Mean	Mdn	Min	Max	SD
Owner-operator	2.29	2	1	3	0.76	9.67	11.20	0.60	16.10	5.32
Professional	3.17	3	2	5	1.17	8.28	8.30	8.00	8.50	0.21
Overall	2.69	3	1	5	1.03	9.20	8.50	0.60	16.10	4.20

Descent Characteristics Observed

Pilots and Behaviors				Means			
Flew VNAV Profile	Met Crossing Restriction	Exceed Speed	Number of Pilots	Descent Rate	DQO Crossing Altitude	Descent Airspeed	Speed Difference
No	Yes	No	3	-1267	14902	216	5
No	Yes	Yes	3	-1900	9778	248	39
No	No	--	6	-1583	12340	232	22
No	No	No	1	-1100	19999	154	-55
No	No	Yes	3	-3817	18300	237	25
No	No	--	4	-3138	18725	217	5
Yes	Yes	No	2	-2500	16962	211	3
Yes	Yes	Yes	1	-2000	17115	239	30
Yes	Yes	--	3	-2333	17013	220	12

Time Required for Programming Reroute and Descent to Meet the DQO Crossing Restriction[1]

	All Participants			Owner-Operators			Professional Pilots		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Did not interleave other tasks	2	0:02:20	0:00:45	1	0:02:52	N/A	1	0:01:48	N/A
Interleaved other tasks	5	0:03:31	0:01:28	3	0:03:21	0:01:49	2	0:02:57	0:01:28

[1] Times were determined using data only from those participants who had successfully completed all reroute and descent programming, including deleting old waypoints, by the time they had reached DQO.

Count of Errors Committed During Reroute

	All Participants (n = 13)	Owner-Operators (n = 7)	Professional Pilots (n = 6)
Did not cross DQO	1	0	1
Programmed DQO after passing MXE	5	3	2
Did not enter all the new waypoints in the reroute	4	1	3
Left incorrect waypoints in flight plan	7	4	3
Entered a waypoint not part of the reroute	1	1	0
Did not meet DQO crossing restriction and did not inform ATC	4	2	2
Communication/Readback errors[1]	29	16	13
Total number of errors	51	27	24
Average number of errors per participant	3.92	3.86	4.00

[1] Communication or readback errors committed by all 13 participants.

Pilot Demographics by Problems Encountered with the Reroute or Meeting the Crossing Restriction

		Reroute				Crossing Restriction at DQO			
		Problems (n = 7)		No Problems (n = 6)		Did not Meet (n = 4)		Met (n = 9)	
		M	SD	M	SD	M	SD	M	SD
	Age	49	12.65	48.83	7.55	48.75	11.70	49.00	10.21
General Flying Hours	Total	3918.57	2510.00	4092.67	1697.69	2525.00	1789.55	4654.00	1941.32
	Past year	245.29	163.74	213.33	151.78	196.00	99.84	245.89	174.13
	Past 3 months	48.57	29.26	57.33	33.49	43.75	21.75	56.56	33.76
	Single pilot jet	273.57[a]	143.02	399.33[a]	474.96	476.25[b]	579.76	267.33[b]	146.86
Citation Specific Hours	Past year	178.29	110.15	125.00	53.68	123.25	23.14	167.22	105.72
	Single pilot in past year	167.86	117.40	104.17	68.82	73.75	44.23	167.22	105.72

DISCUSSION: The programming strategy found to be most successful was to quickly input DQO as the next waypoint after MXE, prior to actually arriving at MXE; and then complete the more time-consuming tasks of entering the rest of the reroute, programming the crossing restriction, and deleting non-pertinent waypoints. Some participants programmed a vertical path (VPTH) descent to meet the crossing restriction at DQO at the same time that they added DQO to their flight plans. This eliminated the need to reselect DQO later after completing other tasks associated with the reroute (e.g., entering the rest of the reroute, deleting old waypoints) to complete the programming. This increased the likelihood that the descent to meet the restriction was initiated on time, even if the pilot was engaged in other tasks.

When time is short and workload is high, inserting new waypoints one at a time while interleaving other tasks may be necessary. Unless the legs between waypoints are very short, pilots may be able to enter them before the waypoints are crossed, even when interleaving other tasks. Although this strategy may be necessary on occasion, it is probably not ideal since it increases vulnerability to forgetting to insert all the new waypoints.

SEE ALSO: Burian, B. K., & Dismukes, R. K. (2007). Alone at 41,000 feet: Single-pilot operations in technically advanced aircraft. Aero Safety World, (11), 30-34 *and* Burian, B. K., Pruchnicki, S. M., Rogers, J., Christopher, B., Williams, K., Silverman, E., Drechsler, G., Mead, A., Hackworth, C., Runnels, B. (2012). Single-Pilot Workload Management in Entry Level Jets. Report submitted. Washington, DC: FAA and NASA.